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Abstract

Abstract. DIII-D plasmas at very low density exhibit onset of n=1 error field (EF) penetration (the `low-density locked mode') not at a critical density or EF, but instead at a critical level of runaway electron (RE) intensity. Raising the density during a discharge does not avoid EF penetration, so long as RE growth proceeds to the critical level. Penetration is preceded by non-thermalization of the electron cyclotron emission, anisotropization of the total pressure, synchrotron emission shape changes, as well as decreases in the loop voltage and bulk thermal electron temperature. The same phenomena occur despite various types of optimal EF correction, and in some cases modes are born rotating. Similar phenomena are also found at the low-density limit in JET. These results stand in contrast to the conventional interpretation of the low-density stability limit as being due to residual EFs and demonstrate a new pathway to EF penetration instability due to REs. Existing scaling laws for penetration project to increasing EF sensitivity as bulk temperatures decrease, though other possible mechanisms include classical tearing instability, thermo-resistive instability, and pressure-anisotropy driven instability. Regardless of first-principles mechanism, known scaling laws for Ohmic energy confinement combined with theoretical RE production rates allow rough extrapolation of the RE criticality condition, and thus, the low-density limit to other tokamaks. The extrapolated low-density limit by this pathway decreases with increasing machine size and is considerably below expected operating conditions for ITER. While likely unimportant for ITER, this effect can explain the low-density limit of existing tokamaks operating with small residual EFs.